Wakefield Accelerator Drives Tomorrow's High-Energy Physics Research

ARGONNE NATIONAL LABORATORY

Challenge

High-energy physicists cause beams of particles to collide in large accelerator facilities to create and study fundamental states of matter that have not existed since the Big Bang. However, for economic and technical reasons, the conventional, klystron-powered units typically used to accelerate particles cannot be scaled up for use in the next generation of colliders that will support particle physics research throughout the 21st century.

For researchers to continue advancing their knowledge of the fundamental nature of matter, a new type of accelerator is needed. Ideally, the new technology will feature extremely high-energy particle intensities, with relatively low power consumption, in a shorter linear structure.

Argonne Solution

Argonne researchers have successfully completed, for the first time, a proof-of-principle test of a beam-based "wakefield" electron accelerator. This technology has the potential to accelerate electrons to higher energies within shorter distances, while requiring less energy, than conventional accelerators.

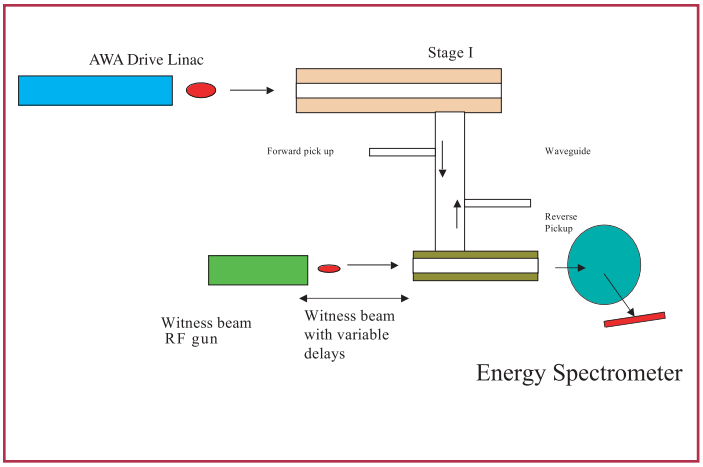

Figure 1. Setup for a dielectric-based, two-beam wakefield acceleration experiment.

The Argonne approach uses the dielectric-based two-beam acceleration method, which sends two beams through dielectric waveguides. It is the simplest of the candidate technologies and the closest to existing accelerator technology (Figure 1).

How Does the Technology Work?

The Argonne Wakefield Accelerator works on the principle that electrons can be accelerated by "riding" in the wake of a high-charge beam sent through a plasma or a vacuum tube made of dielectric material. The leading beam consists of a high-intensity electron beam generated by a special laser. The energy from the leading beam is transferred to a "witness beam," accelerating that beam to a very high level of energy (Figure 2). By analogy, the wakefield technique boosts the energy of a beam in a linear particle accelerator in much the way that a wave on the ocean accelerates a surfer.

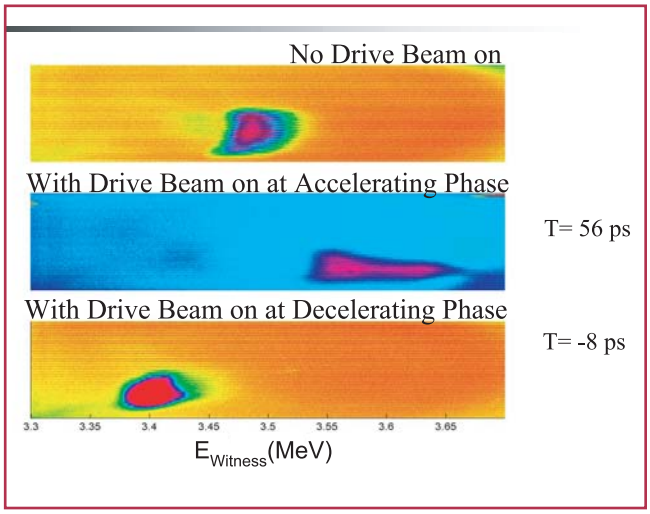

Figure 2. Measured energy of the witness beam at the Argonne Wakefield Accelerator.

Accomplishments

The researchers associated with the Argonne Wakefield Accelerator have achieved the following:

- Generated a record high-intensity leading beam (20-100 nC, 15–40 ps).
- Accelerated a second, witness beam to more than 15 MV/m in dielectrics and more than 60 MV/m in plasmas.
- Demonstrated the first-ever dielectric-based, two-beam accelerator to prove the experimental principle and also produced a detailed map of the acceleration field.
- Constructed both an x-band standing wave and an x-band traveling wave dielectric accelerator for high-power testing.
- Fabricated and installed a new RF photocathode gun and upgraded the facility with controls, laser optics, and diagnostics (Figure 3).
- Investigated new types of dielectric-based accelerator structures (hybrid and rectangular).

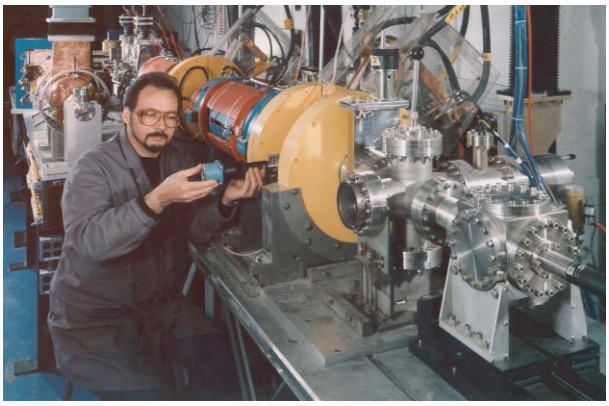

Figure 3. An Argonne scientist calibrates a beamline at the Wakefield Accelerator facility.

Impact

The Argonne Wakefield Accelerator has rapidly advanced the physics and technology of beam generation and acceleration and has the potential to change the face of high-energy physics. It can accelerate particles to very high energies in short distances and is a leading candidate to power the next generation of high-energy accelerators, particularly for linear colliders.

Collaborators

European Organization for Nuclear Research (CERN)
DULY Consulting
Fermi National Accelerator Laboratory
Los Alamos National Laboratory
Naval Research Laboratory/Stanford Linear Accelerator Center (SLAC)
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